

# Specifications and Transmission Line Practicalities

## Introduction

This section focuses on two of industries most widely used balanced transmission line standards, the EIA RS-422 and the EIA RS-485. After reviewing key aspects of these standards, the reader will be introduced to the practicalities of implementing a differential transmission scheme. Finally, several new additions to Texas Instruments EIA product range will be discussed and where appropriate, their application.

## EIA RS-422 AND RS-485 SERIAL COMMUNICATIONS

### • Multipoint Communication Standards

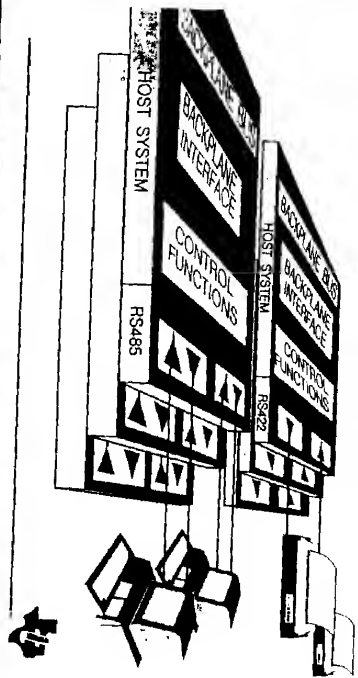


Figure 01 - EIA RS-422 and RS-485 Serial Communications

## The Need for Balanced Transmission Line Standards

High speed data transmission between computer system components and peripherals over long distances, under high noise conditions, usually proves to be very difficult if not impossible with single-ended drivers and receivers. Recommended EIA standards for balanced digital voltage interfacing provide the design engineer with a universal solution for long line system requirements.

RS-422 and RS-485 are balanced (differential) digital transmission line interfaces developed to incorporate and improve upon the advantages of the current-loop interface and improve on the EIA-232 limitations. The advantages are:

- Data rate - to 10M baud and beyond
- Longer line length - up to 1200 metres
- Differential transmission - less noise sensitive

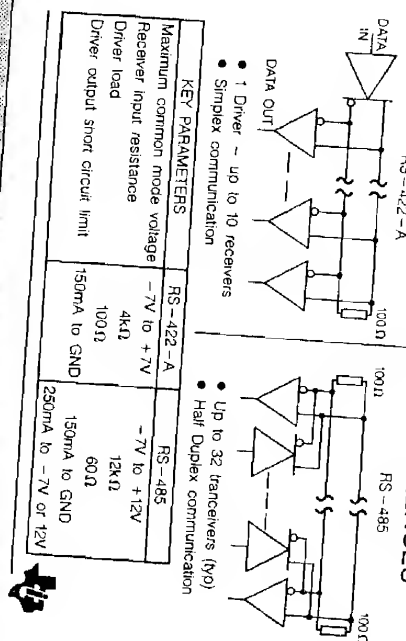
## Application Areas

RS-422 offers a reliable multipoint one way communication. A typical application area is its use in transmitting data from a central computer to multiple remote monitors, printers or stations, such as airport arrival and departure monitors.

RS-485 is an upgraded version of RS-422 extending the number of peripherals and terminals that a computer can interface to, particularly where longer line length or increased data rates are called for. Additionally, RS-485 allows for bidirectional multipoint party line communication and can effectively be used for "mini-LAN" applications, such as data transmission between a central computer and remote intelligent stations. For example, between point of sales terminals and a central computer for automatic stock debiting.

As a result of its versatility an increasing number of standard's committees are embracing the RS-485 as the electrical specification of their standard. Examples include the ANSI (American National Standards Institute) Small Computer Systems Interface (SCSI).

## RS-422-A & RS-485 DIFFERENCES



**Figure 02 - EIA RS-422-A and EIA RS-485 Differences**

### EIA RS-422-A

The balanced transmission line standard EIA RS-422 was developed in 1975 to interface a host computer's data, timing or control lines to its peripherals. The standard was revised (RS-422-A) in December 1978 bringing it in line with its present specifications.

A RS-422 line allows for only one way communication (simplex mode) but by using a differential twisted pair transmission media (not specified in std.) and a RS-422 receiver with its minimum 7V common mode voltage capability makes it less susceptible to noise picked up in hostile environments, via the long cables allowed by the standard. Each driver can drive up to 10 receivers. The specification in the standard places no restrictions on minimum or maximum operating data rates but rather on the relationship of transition speed to a unit interval. However, data rates up to 10M baud are supported and a line length up to 1200 metres is given as guide-line, but not at the maximum data rate.

When operating at low data rates (below 200k baud), or at any speed where the ratio of the driver's output rise time to the one-way propagation delay time of the cable exceeds ten, the cable will not act as a true transmission line and therefore termination is not absolutely necessary. Under all other conditions, the cable loading can no longer be considered as a lumped parameter but must be considered as a transmission line.

The characteristic impedance of twisted pair cable is a function of frequency and cable type, however typical twisted pair cable impedances lie in the range of 100Ω to 120Ω. A

termination resistor with an impedance similar to the cable's characteristic impedance should be connected at the furthest end of the cable.

### RS-485

Increased use of balanced data transmission lines in distributing data to several system components and peripherals over relatively long lines brought about the need for multiple driver/receiver combinations on a single twisted pair line. Hence, an upgraded version of EIA RS-422-A, named EIA RS-485, was introduced in 1983.

RS-485 takes into account RS-422 requirements for balanced-line data transmission plus additional features allowing for multiple drivers and receivers. The guide-lines for data transmission speed, cable lengths and media are the same as for RS-422.

### The Differences

The differences between the RS-485 standard and the RS-422 standard lie primarily in the features that allow reliable multipoint communications.

### Driver features

1. One driver can drive as many as 32 unit loads (one unit load is typically one passive driver and one receiver).
2. The driver output, off-state, leakage current shall be 100µA or less with any line voltage from -7V to +12V.
3. The driver shall be capable of providing a differential output voltage of 1.5V to 5V with common-mode line voltages from -7V to 12V.

4. Drivers must have self protection against contention (multiple drivers contending for the transmission line at the same time).

### Receiver features

1. High receiver input resistance, 12kΩ minimum.
2. A receiver input common-mode range of -7V to 12V.
3. Differential input sensitivity of ±200mV over a common-mode range of -7V to 12V.

### Notes

Line Drivers, Receivers and Transceivers for RS-422 and RS-485

Texas Instruments has a wide range of devices supporting these standards as specified in the following tables:

APPLICATION	DEVICE FUNCTION	DEVICES PER PACKAGE	DEVICE TYPE
EIA Standard  RS-422-A	Drivers	2	SN75158
			SN75159
			SN75ALS191 <sup>1</sup>
			UA9638C
			AM26LS31C
			AM26C31 <sup>2</sup>
	Receivers	4	MC3487
			SN75151
			SN75153
			SN75ALS192 <sup>1</sup>
			SN75ALS194 <sup>1</sup>
			SN75146
		2	SN75157
			UA9637A
			UA9639C
			AM26LS32A
			AM26C32 <sup>2</sup>
		4	MC4386
			SN75ALS193 <sup>1</sup>
			SN75ALS195 <sup>1</sup>

APPLICATION	DEVICE FUNCTION	DEVICES PER PACKAGE	DEVICE TYPE
EIA Standard  RS-485  and  EIA Standard  RS-422-A	Drivers	4	SN75172
			SN75174
			SN65173
	Receivers	4	SN75173
			SN75175
			SN65LBC176 <sup>2</sup>
	Transceivers	1	SN75LBC176 <sup>2</sup>
			SN65176B
			SN75176A <sup>1</sup>
			SN75176B
			SN65ALS176 <sup>1</sup>
			SN75ALS176 <sup>1</sup>
			SN75ALS176A <sup>1</sup>
			SN75ALS176B <sup>1</sup>
			SN75177B
		3	SN75178B
			SN95176B
			TL3695
			SN75ALS170
			SN75ALS171
	Drivers / Receivers	1 / 1	SN75179B
			SN65ALS180 <sup>1</sup>
			SN75ALS180 <sup>1</sup>
			SN75177 <sup>1</sup>
		2 / 2	SN751178 <sup>1</sup>

- NOTES: 1. New product release  
2. Product under development

Detailed Description of Key RS-485 Specifications

The following text describes in some detail the key specifications embraced by the RS-485 standard.

Notes

## Generator (Driver Characteristics)

The open circuit test (left in figure). Used to define the differential and single-ended voltage range for the logic states as follows:

For either logic or binary state, the magnitude of the differential voltage,  $V_o$  measured between the two driver output terminals shall be not less than 1.5V and not more than 6V, and the magnitude of  $V_{oa}$  and  $V_{ob}$  measured independently between each generator output terminal and generator circuit ground shall be not more than 6V.

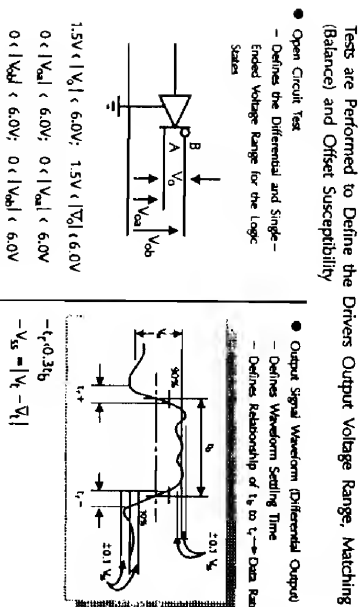


Figure 2a- Generator (Driver Characteristics)

The output signal waveform - differential output (right in figure). This defines both the waveform settling time and the relationship between the waveform unit interval ( $t_b$ ) and the waveform rise time ( $t_r$ ). It is this relationship which sets the limit on the data rate achievable, using the RS-485 standard. (Note, the same rule applies for the RS-422 specification but with a relaxed ratio, see previous section). The differential output voltage, measured across the test load, 54Ω in parallel with 50pF, should have a monotonic transition between the binary states. Thereafter, the signal voltage shall not vary by more than 10% from the steady state value of  $V_{ss}$  (the differential voltage between the two states of the generator output), until the next binary transition occurs. The instantaneous magnitude,  $V_i$  and  $\overline{V_i}$  of either binary state shall not exceed  $V_{ss}$  or 5V.

RS-485 defines the maximum data rate of a device in terms of the transition time,  $t_r$  relative to one unit interval,  $t_b$ . If the transition time for a device is known then the maximum operating data rate,  $t_b$  for RS-485 conditions can be calculated as follows:

$$t_r = 0.3 t_b \text{ or } t_b = t_r / 0.3:$$

For example, the SN75ALS176 has a specified maximum transition rise time ( $t_r$ ) of 8ns. At worst case the maximum data rate would be:

$$t_b = 0.3/(8ns) = 37.5M \text{ baud.}$$

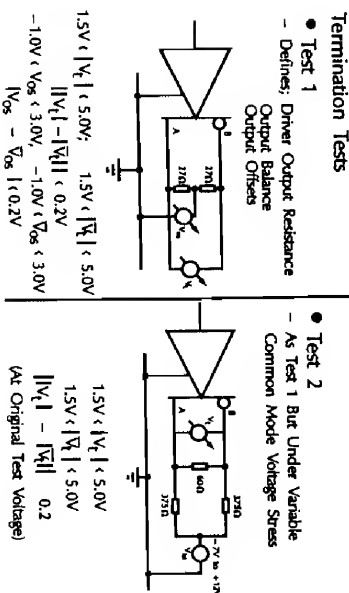


Figure 2b- Generator Tests Continued

There are two termination tests carried out: Test one defines the output resistance, balance and offsets of the driver. With the test load as shown, the magnitude of the differential voltages,  $V_i$  and the offset voltages,  $V_{os}$  should be as specified. The balance, difference between the magnitudes of the differential outputs, of the driver should be within 200mV. Where the offset, or common-mode output, voltage of the driver should not be less than -1V and not more than 3V.

Test two is used to measure the magnitude of the differential voltages,  $V_i$ , under worst case common-mode signal (-7V to 12V) conditions. The circuit is loaded as shown on the right hand side of the figure and should yield the results as stated.

## Notes

## Receiver Characteristics

The two main tests carried out on the receiver are the sensitivity test and the balance measurement used to give an indication of the receiver's ability to reject common mode signals.

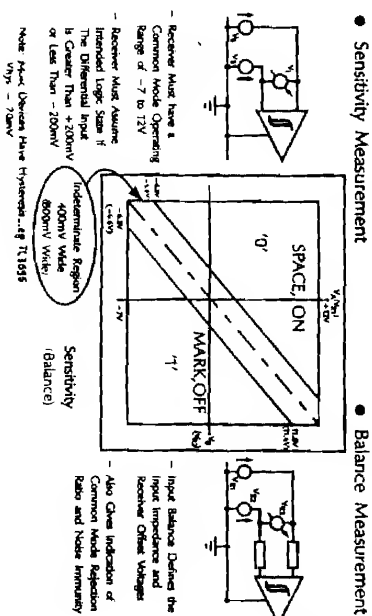


Figure 2c: Receiver Characteristics

## Sensitivity and Balance Measurements

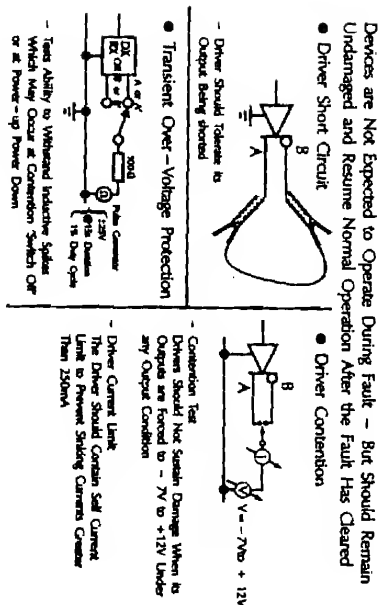
**Sensitivity measurements.** The maximum range of input voltages appearing at the receiver input terminals measured with respect to receiver common shall be between -7V and 12V. For any combination of receiver input voltages within the allowed range, the receiver shall assume the intended binary state with an applied differential input voltage of  $\pm 200\text{mV}$  or more. To avoid faults from noise on slow rising/falling signals, receivers usually have hysteresis incorporated in to their input stages. E.g. TL3695  $V_{thys} = 70\text{mV}$ .

**Input balance measurements.** This defines the input impedance and receiver offset voltage and gives an indication of how well a device rejects common-mode signals. With a test configuration as shown, a differential signal of  $\pm 400\text{mV}$  is applied through two equal valued (1500 Ohm (number of unit loads) series resistors. With this signal applied, the receiver output shall remain in the intended binary state throughout the -7V to 12V common-mode range.

## Fault Conditions

The RS-485 standard has been designed with the realities of long distance and high data rate communication in mind. Therefore the standard takes great care in ensuring that adequate fault protection and robustness is built into devices claiming RS-485 conformance. Detailed in the following figure are just some of the tests used to ensure device robustness.

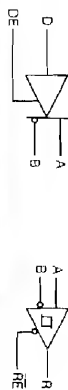
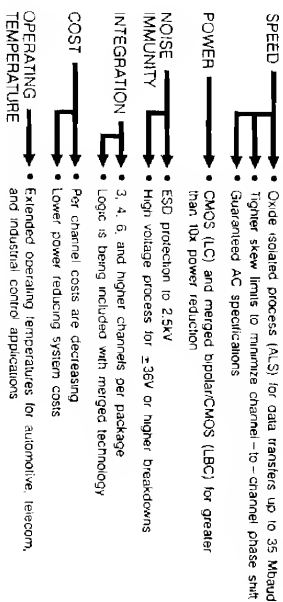
Figure 2d - Fault Conditions



However, it should be noted that even with the precautions taken by the RS-485 standard some applications demand even greater levels of fault protection and tolerance. Excessive and damaging voltage (more than  $\pm 25\text{V}$ ) stress on the receiver inputs can be clamped with appropriate circuitry - while excess common-mode voltage exceeding the maximum specified range (-7V to 12V) by the standard, can usually be avoided by effective grounding techniques and choice of shielded twisted pair cables as transmission media.

Notes

## RS422/485 TRENDS



**Figure 03 EIA RS-485 /422 Product /Application Trends**

Many propriety systems designers are beginning to recognise the inherent advantages of a balanced, differential, transmission scheme over the single ended interface. Such advantages are higher noise immunity, lower noise emissions and improved signal quality. These facts are also not lost on independent standards committees which are starting to embrace RS-485 as the electrical part of their overall specification. Furthermore those systems not following the RS-485 specification verbatim are recognising the virtues of Texas Instruments range of differential driver/receivers, particularly the high speed/low power ALS options.

Representatives of those standards bodies employing a differential transmission scheme can be found in most industries, some examples are listed below:

- Computer:** The ANSI-X3T9.2-1986 Small Computer Systems Interface (SCSI)
- Computer:** ANSI X 3129-1986 Intelligent Peripheral Interface (PI)
- Automotive multiplex Wiring:** CAN, VAN and SAE J1850
- Telecommunications:**
- Factory Automation:** P-Net (A derivative of Field bus)

Each one of these application areas makes its own demands on the processing technology used. Examples of these demands are guaranteed AC specifications and increased data rate capability. In particular, tighter skew specifications are needed for both telecommunication and computer applications, however the interpretation of skew can differ. For example, telecommunication applications are more concerned with device skew, that is the difference between the positive and negative edges of the differential output voltage. A low skew value in this case would represent a lower likelihood of noise radiation. For the

computer application, SCSI, a low bus skew is required. In a SCSI there can be as many 18 differential lines, obviously for timing purposes it is desirable to have low skew between each channel. For these types of applications a high speed bipolar process like the advanced low power scotchky would be required.

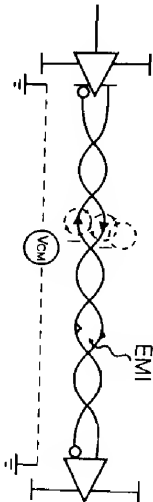
Key requirement across most application areas is low power consumption, particularly with the emergence of battery backed or operated equipments. This requires a low power technology, for example CMOS. However although time for controller applications, CMOS is not generally suitable for line drive/receive functions, here a more robust technology is needed, for example, a bipolar or merged technology like Texas Instruments' LinBiCMOS combination of analogue bipolar and analogue CMOS).

Due to the increasing use of differential systems, particularly in electrically hostile environments, increased common mode voltage ranges and low susceptibility to ESD (Electro-Static Discharge) damage is required. Furthermore, extended temperature ranges are required particularly in automotive applications where the line drive/receive functions may be located under the car bonnet (hood). All new devices in Texas Instruments' range of line drivers and receivers contain temperature range options for both commercial,  $0^{\circ}C$  to  $70^{\circ}C$  and industrial,  $-40^{\circ}C$  to  $85^{\circ}C$ . Some devices like the SN65076 have been designed especially for automotive applications by offering a  $-40^{\circ}C$  to  $105^{\circ}C$  temperature range.

The final demand made by all types of equipment is for increased integration. Designers are requiring increased functionality from semiconductor chips and, perhaps an even more importantly require that these chips be less expensive than the solution(s) they replace.

Notes

## DIFFERENTIAL LINE CONSIDERATIONS



System	Advantages	Disadvantages
Differential RS-422 V-11 RS-485	<ul style="list-style-type: none"> <li>Noise &amp; cross talk rejection</li> <li>Ground shift rejection</li> <li>Higher data rates</li> <li>longer line lengths</li> </ul>	<ul style="list-style-type: none"> <li>More signal wires</li> <li>Moderate to high cost</li> <li>More complex</li> </ul>
Single-ended RS-232 V-28 RS-423 V-10	<ul style="list-style-type: none"> <li>Low cost</li> <li>Simple</li> </ul>	<ul style="list-style-type: none"> <li>Susceptible to                             <ul style="list-style-type: none"> <li>Noise &amp; crosstalk</li> <li>Ground shifts</li> </ul> </li> <li>Low data rates</li> <li>low line lengths</li> </ul>

**Figure 04 - Differential Line Considerations**

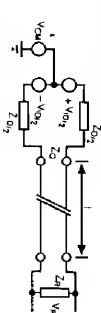
A differential communication system requires the use of two 'signal carrying' wires between driver and receiver, such that the signal current flows in opposite directions in each wire. The net effect of doing this is that the receiver is only concerned with the *difference* in voltage between the two wires. The absolute value of the dc common mode voltage of the two wires is not important. In practice, drivers and receivers have a finite common mode voltage range within which they can operate.

The use of a differential communications interface allows data transmission at high rates and over long distances to be accomplished. This is because effects of external noise sources and crosstalk effects are much less pronounced on the data signal. Any external noise source coupling onto the differential lines will appear as an extra common mode voltage which the receiver is insensitive to. The difference between the signal levels on the two lines will therefore remain the same. By the same argument, a change in the local ground potential at one end of the line will appear as just another change in the common mode voltage level of the signals. The differential output voltage to the line will also provide a doubling of the driver's single-ended output signal. Twisted pair cable is commonly used for differential communications since its twisted nature tends to cause cancellation of the magnetic fields generated by the current flowing through each wire, thus reducing the effective inductance of the pair.

The main disadvantage of a differential system lies in the fact that two cables are required for each communication link. This increases system cost, but provides superior performance when data is to be transmitted at high rates over a long distance.

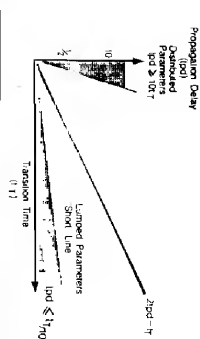
## TRANSMISSION LINE CONSIDERATIONS AND EFFECTS

### • Transmission Line Model



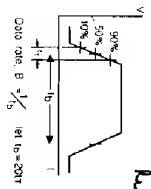
Propagation delay,  $t = \frac{d}{v}$  Total transmission delay =  $\frac{d}{v}$  down line

### • Classification of Lumped and Distributed Systems



### • Signal Shape

- Overshoot
- Stair Case Output
- False Triggering



*Handwritten notes:*  
 $t_{rise} = 1/5$  of  $t_{prop}$   
 rise time = 1/5 of propagation time  
 line = 1/5 of  $t_{prop}$   
 line = 1/5 of  $t_{prop}$

**Figure 05 - Transmission Line Considerations and Effects**

Before design of a digital data link can take place application constraints and an understanding of the signal's characteristics must be understood. More specifically, a method of identifying the class of data link, and any special design techniques required must be made.

A digital data link can be classed in two modes:

- A transmission line (distributed parameter model)
- Short wire (lumped parameter model).

A distributed parameter model considers the connecting circuit in terms of distributed parameters (inductance, capacitance, resistance, conductance), rather than as an equivalent lumped load on the line. The transmission line can be considered in terms of an infinite number of small filter sections making up the line. The result is that a transmission line is said

## Notes

to have a characteristic impedance,  $Z_0$ , which is independent of distance along the line and represents the voltage and current relationship for a wavefront at any point as it travels along the line.

The transmission line will always consist of two conductors, with the current flowing in opposite directions in each of the conductors. In the single ended case, one of these conductors is the ground wire.

The speed that a pulse travels at along a transmission line approaches that of the speed of light. The type of cable used will provide the limit to the actual speed.

All cables can be thought of as transmission lines, but the term, transmission line, is used with differing meanings. If the signal starts to change at the driver's output at one end of the line, the effect of this change will eventually be seen at the other end of the line. A reflection of the signal will occur, which will eventually return back to the driver terminals. If this happens before the original transmitted signal has risen to its peak value then the line will normally be treated as a lumped parameter system rather than as a true transmission line. This is because the line itself does not greatly influence the performance of the system. A general rule of thumb for determining if a system should be treated as a true transmission line can be formulated. If the rise time,  $t_r$ , of the signal is much less than the round trip propagation delay,  $2t_{pd}$ , of the signal from driver to receiver and back to driver, then the cable can be treated as a transmission line and not as a lumped parameter model. A better model is given by allowing  $10$  one way propagation delays,  $t_{pd}$ , to occur during the transition edge time.

When the cable is operating like a transmission line, extra loads in the form of drivers and receivers can be added, providing that they do not cause too great a shunting effect on the line. These extra loads, if evenly distributed along the line, can be treated as an extra distributed capacitance along the line adding to the effect of the line capacitance and inductance. The extra devices will decrease the line impedance and reduce the speed of the signal along the line.

In the case of the lumped parameter model, the line tends to represent a pure fixed load to the driver device. For example, the capacitance of the line will be modelled as a fixed value which effectively limits the output voltage slew rate of a driver device that can supply a finite amount of current to the line.

## Line Termination

It is generally good design practice to terminate the ends of lines which are classified as transmission lines. Here the golden rule is to match the impedance from the source of the driver to the characteristic impedance of the cable, and from the cable to the characteristic impedance of the receiver. If there is an impedance discontinuity at any junction, then the signal will be reflected from the mismatch. This will lead to signal distortion which in turn leads to either a falsely triggered receiver or excessive propagation delay. Calculation of a suitable value for this termination value will be dealt with later in this section whilst a more detailed discussion can be found in the glossary section.

## DATA RATE/LINE LENGTH LIMITATIONS

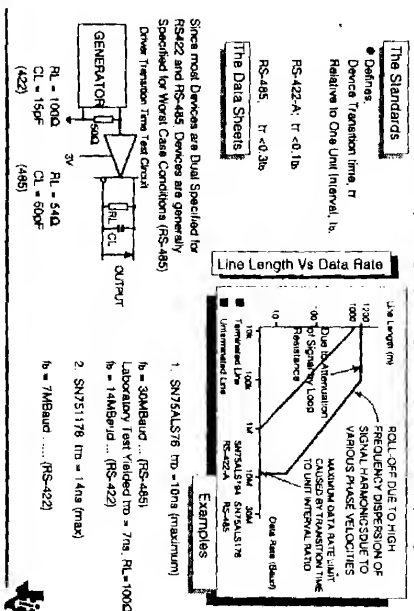


Figure 06 - Line Length and Data Rate Limitation

Most application areas will demand some kind of compromise between the line length used and the data rate required, particularly if distortion in its many guises is to be avoided. A first, all important, step in understanding what compromises are necessary is to recognise the various forms of distortion and why they occur.

No transmission line is perfect, even by sending current down the line some voltage drop will occur due to the resistive nature of the line, this in its most simplistic form is distortion. This is compounded when longer line lengths are used where the attenuation from source to destination can cause quite severe distortion. This places a limit on the line length even at low data rates as shown in the top right hand corner of the figure.

A typical cable of 24 SWG can have a series resistance of  $80 \Omega$  per km, and so the line length will be limited to the order of 1200m (series resistance equals the line's characteristic impedance).

## Notes

## The Standards

Another limitation of system performance are the speed limitations of the line elements themselves. No device, no matter what technology used, will have zero propagation delays and transition times. The trick is to ensure that any delay introduced by these delays is insignificant in comparison to the line propagation delay. To ensure the device does not introduce distortion, i.e. to maintain signal shape, it is good design practice to set a time between the unit interval,  $t_U$ , and the transition rise time,  $t_r$ . This limitation is often specified as the standard being used. For RS-422-A the ratio of  $t_r$  to  $t_U$  is 1:10, and for RS-485 1:3.

## The Data Sheets

Many devices within Texas Instruments' range are specified for both RS-422 and RS-485 operation. The differing specifications of relating  $t_r$  to  $t_U$  between the standards makes the understanding of data rate capability for RS-422 operation difficult to ascertain, since these devices are tested to the worst case conditions of the RS-485 specification. That is, the driver output is driven into a resistive load of 54Ω in parallel with a capacitive load of 50pF.

An example of such a device is the SN75ALS176 which can be used for both RS-422 & RS-485.

## Examples

1. SN75ALS176B has a differential-output transition time  $t_r$  of 10ns(Max).

Therefore:  $t_U = 3.33 \times 10 \times 10^{-9} = 33.3\text{ns}$  giving a minimum theoretical frequency of **30Mbaud**.

As the data sheet specifies a minimum  $t_r = 5\text{ns}$  the maximum theoretical data rate could be as high as 60 Mbaud.

Using the RS-422 data rate test for this device does not give a clear picture as the standard requires a lighter load to be applied. However, laboratory test using the RS-422 load gives a  $t_r$  for the ALS176 of 7ns (RS-485 load = 14ns) indicating a RS-422 data rate of 14Mbaud.

2. SN75ALS194 has a differential-output transition time  $t_r = 14\text{ns}(\text{Max})$ . Since this device is specified solely for RS-422 we can clearly calculate the minimum theoretical data rate.

Therefore:  $t_U = 10 \times 14 \times 10^{-9} = 10 \times 14 \times 10^{-9}$  giving a minimum theoretical frequency of **7Mbaud**.

Again a more aggressive data rate could be achieved if the typical specified value for  $t_r = 8\text{ns}$  was used. Giving a typical frequency of 12.5 Mbaud.

## Other Effects

Other effects acting upon the transmission line are due to phase distortion introduced on the driver's transition edges. The high speed edges, necessary for high speed systems, have high frequency harmonic content. The inductive and capacitive (and resistive) nature of the line introduces delay and distortion into these harmonics. This in turn reduces the clarity of the signal being sent down the line, thus increasing the probability of error.

This effect is normally measured using eye patterns which measure the jitter and distortion in the signal being sent down the line. It is this effect that causes the predominant reduction in data rate as the line length increases. Another limitation can be caused by incorrect termination of the line, causing reflections. These reflections can cause errors due to loss of timing information.

In conclusion, distortion and thus data integrity is a function of signal rise time and line attenuation. Signal rise time and attenuation are often quoted in manufacturers data, and can be used to determine the line distortion.

## A Discussion of Skew

When driving the line at high speeds the effects of the driver and receiver on the system become more apparent. The size of the delays relative to the unit interval will increase, meaning that asymmetries in the edges can cause extra distortion on the output to the line.

Using differential line systems, the delays through the driver and receiver have different meanings. This is because the driver is really a single ended input to differential output converter, while the receiver is a differential input to single ended converter.

When discussing propagation delays through the driver, two possibilities arise: the propagation delay from the input to one output and the other output (single ended) and also the propagation delay from the input to the differential output (differential).

The single ended propagation delay is normally measured between the input going through 1.5V and the output going through 1.5V, while the differential propagation delay is measured from the input going through 1.5V and the differential output going through its mid-voltage, (in a balanced line 0V across the line).

## Notes

These propagation delays effectively displace the signal on the line in time, but do not distort it; however, differences in the delays from output A going high and output B going low to output A going low and output B going high does cause distortion. The differences between these are termed as the skew in the output. For a single ended measurement it is termed as **Propagation Skew**, while for the differential measurement it is termed **Differential Skew**.

The main effects of propagation skew are that the differential transition edges can be stretched out and that they can become flat around the threshold region of the receiver, i.e., increase the radiated RFI and sensitivity.

The main effect of the differential skew is the asymmetry caused by different differential propagation delays causing one state to be longer than the other state.

The propagation skew is specified on the older differential line drivers, while differential skew is specified on the more modern devices such as Texas Instruments' SN75ALS176.

The receivers are tested on the propagation skew. With one input tied at a reference voltage and the other toggled, giving a single ended propagation delay. The skew in this delay will also cause extra distortion to the signal, especially its timing information, as the periods can be further distorted.

## Practical Considerations

Having reviewed some of the key issues involved in implementing a high speed differentially data link, practical ways in which to overcome some of the problems encountered are now discussed.

The first areas of concern are how to make connections to the line, how and where the line should be terminated and into what value?

### CALCULATION OF TERMINATION RESISTANCE

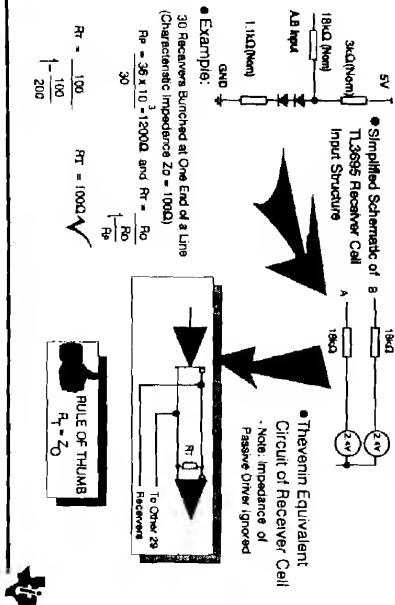


Figure 07 - Calculation of Termination Resistance

For better performance, the transmission line needs to be terminated by a resistor of a value close to its characteristic impedance. One question that immediately arises is the value of terminating resistance required if the line is loaded by other receivers. More specifically, does the receiver's input impedance have any effect?, especially when many receivers may be grouped together at the far end of the line. The following text sets out to prove that for the majority of applications the loading effect of receiver stations can be ignored and as a rule of thumb (working approximation) the value of  $R_T$  should equal the characteristic impedance of the line.

In fact, the characteristic impedance varies very little with respect to the physical dimension of the cable. For example a wire over-ground transmission line with a wire diameter equal to the diameter of an electron and a height above the ground plane of 500,000Tm (50 light years) has a characteristic impedance,  $Z_0$ , of 300 $\Omega$ .

Notes

Each input of the receivers has a nominal input impedance of  $18k\Omega$  feeding into a common mode voltage source of 2.4V. It is this configuration which provides the common range of the receiver required for RS-485 systems!

Due to the fact that the each input is biased to 2.4V, the normal common-mode voltage balanced RS-485 systems, the  $18k\Omega$  resistors on the inputs can be taken as being in series across the input of each individual receiver.

If thirty such receivers are placed close together at the end of the line, they will tend to react as thirty  $36k\Omega$  resistors in parallel with the termination resistor. This overall effective resistance will need to be close to the characteristic impedance of the line.

The effective parallel receiver resistance,  $R_p$ , will therefore be equivalent to:

$$R_p = 36 \times 10^3 / 30 = 1200\Omega$$

While the termination resistor,  $R_T$ , used will be equal to:

$$R_T = R_p / [1 - R_p/R_p]$$

Thus for a line with a characteristic impedance of  $100\Omega$ , the termination resistor  $R_T$  should be:

$$R_T = 100 / [1 - 100/1200] = 110\Omega$$

Since this calculated value is within 10% of the line characteristic impedance the value chosen for the line termination resistor,  $R_T$ , will normally be equal to the characteristic impedance,  $Z_0$ .

## METHODS OF CONNECTION

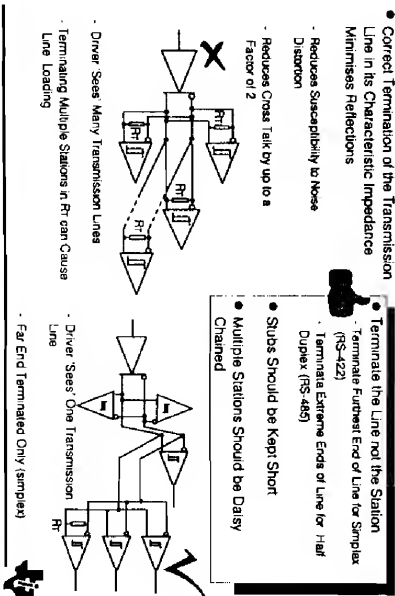


Figure 08 - Methods of Connection

### Methods of Connection

The way in which stations are connected to the line needs careful consideration. Furthermore methods of line termination and device positioning must be considered. There are two basic methods of connection:

- The star connection
- The daisy chain connection

Considering the star connection, the transition edge from the driver will be loaded by a group of separate transmission lines, rather than one. Each transmission line boundary will cause a change in impedance resulting in reflections.

Notes

Another situation to avoid is the termination of multiple stations, since this could excessively load the driver. Termination at the extreme ends for RS-485 (half duplex) and far end only for RS-422 is recommended. Normally stubs (taps of the main line) should be kept as short as possible so not to appear as transmission lines themselves.

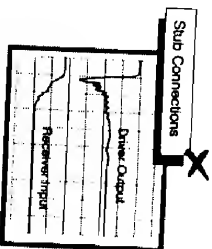
The recommended method is to use the daisy chain, a configuration where the transmission line continues from one receiver to the next and only the last receiver on the chain is terminated. This means that the transmission line and hence the driver will see one continuous transmission line with only one termination resistor. Each tap-off will in effect be a stub, but in this case they will not be all grouped together and will be kept very short to reduce their effect.

## METHODS OF CONNECTION...

### Measurement Information

$$V_1 = V_2 = 2V_{DDV}$$

$$I = 50mA/DIV$$



### Cable Specification

- Flat Ribbon Cable with Parallel Copper Wires - ULL2651
- Capacitance Between Adjacent Lines = 49.2pF/m
- Line Length 2 m from End to End
- Characteristic Impedance (Z0) = 105Ω

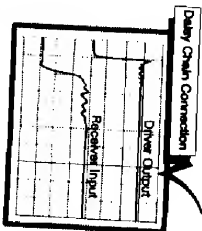


Figure 09 - Methods Of Connection...

### Comparing the Quality

The figure shown, further confirms the need for keep stub lengths short and the use of correct termination techniques by comparing the effect on signal quality for the daisy chain, and star method of connection.

In both instances exactly the same application scenario was used as was the same cable specification. The cable used was a flat ribbon cable with parallel copper wire conforming to U.L. specification 2651. Connections were made as shown in the previous figure and the total cable length from source to destination was 2 m.

## CALCULATION OF STUB LENGTH

- Stubs Cause Impedance Discontinuity and Increases Line Capacitance Causing:
  - Overshoot and Undershoot
  - Ringing
  - Reflections

$$U = \frac{1}{78 \times 65 \times 10^{-2}} = 198 \times 10^{-3} \text{ m}^{-1}$$

Using our Thumb

$$\text{Stub} = \frac{100}{10} = 10 \text{ cm} \quad \text{1 = 10 cm} \quad \text{10 = 100 cm}$$

$$\text{Stub} = \frac{100}{10} = 10 \text{ cm} \quad \text{1 = 10 cm} \quad \text{10 = 100 cm}$$

$$\text{Stub} = 1.3 \times 10^{-3} \times 198 \times 10^3 = 258 \text{ mm (100)}$$

Substitution of 1 into 2 gives:

$$U = \frac{1}{Z_0 C_0}$$

Figure 10 - Calculation of Stub Length

In the earlier section a rule of thumb was developed which stated that if signal distortion is to be avoided, all connections to the main line must be kept as short as possible. Distortion in this context could be both amplitude and phase distortion - leading to reflections amongst other undesirable factors.

These connections are usually termed stubs. A stub is a connection to the transmission line from either a driver or a receiver. However, even when short in comparison to the length of the main transmission line it too could exhibit transmission line effects. Any connection to the line will cause an impedance discontinuity, leading to reflection at the stub/transmission line boundary.

To minimise these effects the stub should be kept as short as possible, so that the stub is seen as a lumped (non transmission line) rather than a distributed (transmission line) load to the line.

### Notes

## How Short is Short ?

It has been described earlier that a pair of cables will act as a transmission line if the round trip propagation delay,  $t_{pd}$ , is more than 5 times the transition times of the driver,  $t_r$ . The converse is true if the line is not to operate as a transmission line but as a lumped parameter model. This forms the basis of the stub length calculation given below.

The figure shows a calculation for determining the maximum length of the stub. The rule of thumb that the transition time of the pulse sent down the line should take ten times the time taken for the pulse to propagate to the end of the stub. Resulting in any reflections being incorporated into the transition edge.

From this basis, the length of a stub can be calculated using the cable and driver parameters.

The pulse speed down the line,  $U$ , equals the reciprocal of the product of the line impedance and line capacitance, both of which are normally specified for the cables used.

The propagation delay down the stub should be at the most one tenth of the transition time of the pulse. These facts can be brought together to give the length of the stub,  $l_s$ , as:

$$l_s = t_{rD} / (10)$$

Using the SN75ALS180 and its transition time of 13ns, a cable with a characteristic impedance of 78Ω and line capacitance of 65pF, gives a maximum stub length of 254 mm or ten inches.

The main effect in this case will be a slight increase in the capacitance loading of the line.

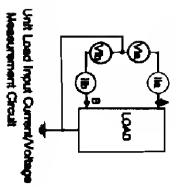
## THE UNIT LOAD CONCEPT

### ● Receiver/Passive Driver Loading of RS-485 Lines (DC)

One Driver can Drive as Many as 32 Unit Loads Under a Maximum Common Mode Voltage and a Total Line Termination of 600Ω or More

### ● One Unit Load is Defined as:

Load Which Allows 1mA of Current to Flow Under a Maximum Common Mode Voltage Stress of 12V



### ● Examples

SN75117B (Dual Driver/Receiver)  
 $I_{CC} = 0.1mA @ 7V to 12V$ ,  $I_L = 1mA @ 12V$  (worst case)  
 $U_L = 11 - 11 U_L$   
 $I_L = 32 = 32$  Driver Cables  
 $1 \frac{1}{1}$   
 TL060C (Transceiver)  
 $I_L = I_{CC} = 1.5$   
 $1.5$   
 $0.07mA$   
 4.7 Ohms per RS485 line  
 $U_L = 0.4$

Figure 11 - The Unit Load Concept

## Line Loading Considerations

One final consideration needed to implement a digital data link is the number of driver/receiver elements that can be connected to the line. This is now discussed:

### The Unit Load Concept (RS-485)

The maximum number of drivers and receivers that can be placed on a single communication bus depends upon their loading characteristics relative to the definition of a unit load (U.L.). RS-485 recommends a maximum of 32 unit loads per line.

One U.L. (at worst case) is defined as a load that allows 1 mA of current under a maximum common-mode voltage stress of 12 V. The loads may consist of drivers and/or receivers but

Notes

does not include the termination resistors, which may present additional loads as low as 80 total.

The first example shows a unit load calculation for the dual SN751178 driver/receiver which offers a unit load value of 1.1 U.L. - meaning 29 such devices could be connected on one line. In the second example the TL3695 transceiver is used. Since this device is internally connected as a transceiver, ie driver output and receiver input connected to the same bus, it is difficult to obtain separate driver leakage and receiver input currents. For this calculation, reference is made to the receiver input resistance, 18k $\Omega$ , giving a transceiver current of 0.6mA. This can be taken to represent 0.6 U.L. which will allow upto 47 devices to be connected to the line.

Obviously it may be possible to connect more devices than the RS-485 recommendation, but this is at the designers risk.

The graph in the top right corner of the figure is used to define the boundaries of the unit load and works by superimposing the voltage and current characteristics of the load upon a reference trace. A line from -3 V is drawn at a tangent to intercept receiver input current at the 12 V point. Similarly, a line is drawn from -7 to intercept the driver leakage current at the 5 V point. The currents indicated at -7 V and -12 V are then compared to the currents specified by the standard. The larger of the two voltages to current ratios forms the unit load value.

The electrical characteristics should not show any negative resistance otherwise instability and spurious oscillations could occur.

### Total Load Characteristic Limits (RS-422)

In RS-422 the d.c load characteristics is specified much more simply:

The total load including multiple receivers, fail safe circuitry, and cable termination shall have a resistance greater than 90 $\Omega$  between its input points (A and B), ie across the line, or when the cable is left un-terminated the resistance shall be greater than 400 $\Omega$ , and shall not require a differential input voltage of more than 200mV for all receivers to assume the intended binary state.

With a basic understanding of transmission line practicalities, a brief discussion of the range of Texas Instruments products available and their application can begin.

## Products and Applications for EIA RS-422

### SN75ALS19X SERIES FOR RS-422-A

#### Driver technology performance



- ALS - Enhancements
  - 50% lower supply current for both driver and receiver
  - Greater system integration
  - Improved reliability
- Reduced skew
  - Less EMI
  - Increased noise immunity
  - Better symmetry
- Lower propagation delay
  - Ability to operate to 20M bps

DRIVERS	TYPE	IND. STD.	REPLACING	RECEIVERS	TYPE	IND. STD.	REPLACING
SN75ALS192	QUAD	RS-422-A	AM26LS31	SN75ALS193	QUAD	RS-422-A	AM26LS32A
SN75ALS194	QUAD	RS-422-A	MC3487	SN75ALS195	QUAD	RS-423-A	MC3486
SN75ALS191	DUAL	RS-422-A	UA9538	SN75ALS197	QUAD	V10 V11	AM26LS32A
	8-PIN			SN75ALS199	QUAD	X25 X27	MC3486

Figure 12 - SN75ALS19X Series For RS-422

The well proven SN75ALS19X series of drivers and receivers for RS-422-A represents some of the best speed versus power consumption alternatives in the industry today for reliable balanced line transmission over short as well as long distances. The series has found wide use in telecommunication as well as in computer applications.

### ALS Technology Advantages

All ALS products employ Advanced Low-Power Schottky or Impact™ processes. These have been derived from the digital processes and trimmed for linear applications requiring wide common mode voltage operation, tough protection and accurate receiver input threshold

Notes

voltages. ALS technology provides combined improvements in die design, tooling products and wafer fabrication, which in turn, provide lower power consumption and permit much higher data throughput than other designs - in short: speed without the usual power penalty. Standby current is typically reduced by 50% although switching speed has gone up by more than 30% compared with previous LS (Low Power Schottky) parts.

### 50% Lower Supply Current

The significant reduction in power consumption allows for a higher board packaging density and hence greater system integration without increasing temperature due to power dissipation. In addition, a lower operational temperature improves system reliability.

Lower power consumption also permits devices to operate in an extended temperature range (-55°C to +125°C) with fewer constraints.

### 30% Improvement in Data Throughput

Lower propagation delays and reduced skew, combined with lower standby power consumption, allows these devices to operate in excess of 20Mbaud. For example, the SN75ALS192 quad driver is capable of transmitting data at 20Mbaud (50% duty cycle) while only dissipating the same power as an AM26LS31A in standby mode. The maximum achievable data rate is usually determined by maximum power dissipation at the maximum operating temperature. Reference should be made to the datasheet's Dissipation Rating Table.

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### Reduced Skew

Skew for a data transmission driver or receiver is related to the difference in propagation delays from input to output. With different high and low going propagation delays for a device, asymmetry in its output signal occurs, which ultimately reduces the maximum data rate.

When switching the output of the differential driver from one state to the other state, differences in propagation delays from the input to the inverting and non-inverting outputs can cause the differential output voltage to flatten out as it passes through the receiver's threshold region. Clearly, this makes the received signal more vulnerable to noise.

The SN75ALS19x series has been designed with minimum skew to improve symmetry, increase noise immunity and radiate less EMI (Electromagnetic Interference) caused by non-common mode currents in the transmission cable. The high-speed dual driver, SN75ALS191 in an 8-pin package features a typical differential skew of 1.5ns (4ns maximum).

### Products

A wide range of SN75ALS19x products are available as improved pin for pin replacements for industry standard devices.

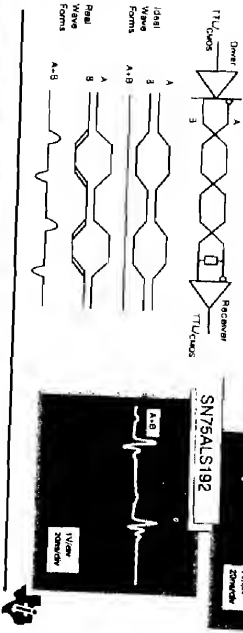
main difference between the quadripole drivers. SN75ALS192 and SN75ALS194, is related to their enabling configuration. SN75ALS192 has a common pin enabling all four drivers, whereas independent enabling schemes are possible for each pair of drivers in the SN75ALS194. Similarly, different enabling schemes distinguishes the quadripole receivers, SN75ALS193 and ALS195. The SN75ALS192 and SN75ALS193 form complementary devices as do the SN75ALS194 and SN75ALS195 devices. Using complementary drivers and receivers together should provide optimum performance.

The quadripole receivers, SN75ALS197 and ALS199 have relaxed input sensitivity requirements of  $\pm 300\text{mV}$ , compared to  $\pm 200\text{mV}$  for SN75ALS193 and ALS195. However, they are available in low cost D (surface mount) or N (DIP) packages and meets CCITT recommendations V.10, V.11, X.26 and X.27.

Notes

## LOW SKEW REDUCES EMI

- Radiated Emission from a twisted pair transmission line relates to the propagation delay skew of the driver.
- Common-Mode Current Spikes on a line produce EMI via the "Transmission Line Antenna".
- Significant Emission Reduction when Using Fast low skew drivers



**Figure 13 - Low Skew Reduces EMI**

### EMI Related to Differential Transmission Lines

Radiated emissions from electronic systems is having more attention paid to it, as mutual disturbances between electronic equipment increase and the subsequent need for EMC regulations becomes more apparent. This is compounded by the increased use of high clock rates and high currents which generate high frequency EMI. Applications placed on printed circuit boards are normally enclosed in a confined space making the problem easier to solve, but when transmitting data signals to the outside world through cables, increasing the total radiated emission by the system is difficult to avoid.

In large computer systems, inter-unit cables within the system have been found to be responsible for much of the radiated emission. Further studies have revealed that the noise itself is a function of common mode current spikes, brought about by the skew between the outputs of clocked differential drivers. Significant improvements in system-wide emissions were seen in practice after replacing high skew driver devices with others those which had less skew.

The effect seen is not only related to large computer systems but is scalable to all systems using differential transmission lines. Differential drivers and receiver are designed to operate under conditions with high common mode signals. Low frequency common mode signals usually cause no problems, but high frequency common mode spikes cause EMI and in systems with inter-unit cabling an antenna is readily available increasing the radiated emission. Clearly, twisted pair cables used to interconnect boards within the same cabinet, or

to establish data transmission between various equipment, using for example the popular standards RS-422-A or RS-485, are likely to radiate EMI if the driver's complementary outputs are not exactly symmetrical. This is true for the single differential line in an industrial system as well as for the many parallel differential lines used in a SCSI interface cable.

### Low Skew Devices Reduce EMI

Ideally, a differential driver should not generate common mode signals due to the nature of the differential output and the twisted cable cancelling the common-mode currents but in practice, small differences between the complementary outputs occur which produce fast common mode pulses on the line.

The skew specification, specified as the propagation delay difference from the input of the differential driver to the driver's respective inverting and non-inverting outputs is a good measure for how much or how little radiation that can be expected from high frequency common mode signals during switching. However, a low skew specification on its own does not guarantee negligible common mode signals as the signals can still be unsymmetrical due to different rising and falling waveforms. In such cases Significant current spikes can be measured on the line.

### Use Fast Devices Even in Low Data Rate System

Even in systems where low data rates are used, EMI can still cause problems with EMC regulations. These problems are best solved by employing high speed devices usually having a significant lower skew than slower drivers.

Consequently, previous low power schottky (LS) designs like AM26LS31 or SN75176 will in general radiate more emissions than newer Advanced Low Power designs like SN75ALS192 and SN75ALS176 or even the new BiCMOS designs like AM26C31 and SN75LBC176. A measurement was made to demonstrate this effect comparing AM26LS31 with SN75ALS192. Evidently, the negligible common mode signals resulting from switching the SN75ALS192 are significantly smaller than the clearly visible common mode current spikes produced by the AM26LS31.

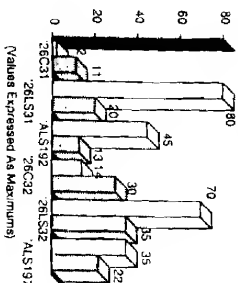
### Notes

## AM26C31/32.... OLD NAME NEW BENEFITS

### Common Features

- ☐ Icc - Power Supply Current (mA)
- ☐ I<sub>p</sub> - Propagation Delay (ns)

- Meets EIA Standards RS-422-A, RS-423-A (Receiver), and CCITT V.11
- Designed Using BiCMOS
- Temperature Range Options:
  - AM26C31C: -0°C to 70°C
  - AM26C31I: -40°C to 85°C



### AM26C31

- Low-Power Quad Driver
- Icc = 800µA (typ)

- Low Pulse Distortion
- t<sub>PHL</sub>(D) = 0.5 ns (typ)

### AM26C32

- Low-Power Quad Receiver
- Icc = 500µA (typ)

- Input Fail-Safe

Figure 14 - AM26C31/32.... Old Name New Benefits

### Improvements in Power Consumption and Speed

Industry has long been aware of the advantages gained from using the quadruple driver AM26LS31 and the accompanying quadruple receiver AM26LS32 for RS-422 type applications. However the old low power schottkey (LS) process is no longer capable of keeping pace with today's demands for high speed and low power. The AM26C31 and AM26C32 are modern upgrades, fabricated using a low power BiCMOS process.

These devices find applications where high speed and low skew are crucial, for example in disk drive and Telecommunication applications. One particular application which would benefit from the low power consumption will be the Central Office Exchange, where due to the sheer number of devices used, power consumption becomes a critical issue - especially when the rest of the system is implemented in low power CMOS.

The figure shows some key benefits of these new designs and compares the power consumption and propagation delay against industry standard devices. It can easily be seen, that the BiCMOS devices not only exhibit a dramatic reduction in power consumption, from 80 mA to 2 mA, but there is also an improvement in ac performance. The AM26C31 driver has a lower propagation delay than any of the devices shown in the graph.

### Description

Both the AM26C31 and AM26C32 have been manufactured using a BiCMOS technology which is a combination of bipolar and CMOS transistors. This process provides the high

drive/current drive of bipolar with the low quiescent power consumption of CMOS. The graphs in the figure show that the power consumption of the AM26C32 receiver is reduced to approximately one-fifth of the standard LS part.

The AM26C31 is a quadruple complementary-output line driver designed to satisfy the requirements of EIA RS-422-A and CCITT recommendation V.11. The three-state outputs have a high-current drive capability for driving balanced lines such as twisted-pair or parallel-wire transmission lines, and they provide a high impedance state in the power-off condition. The enable function is common to all four drivers and offers the choice of active-high or active-low enable input.

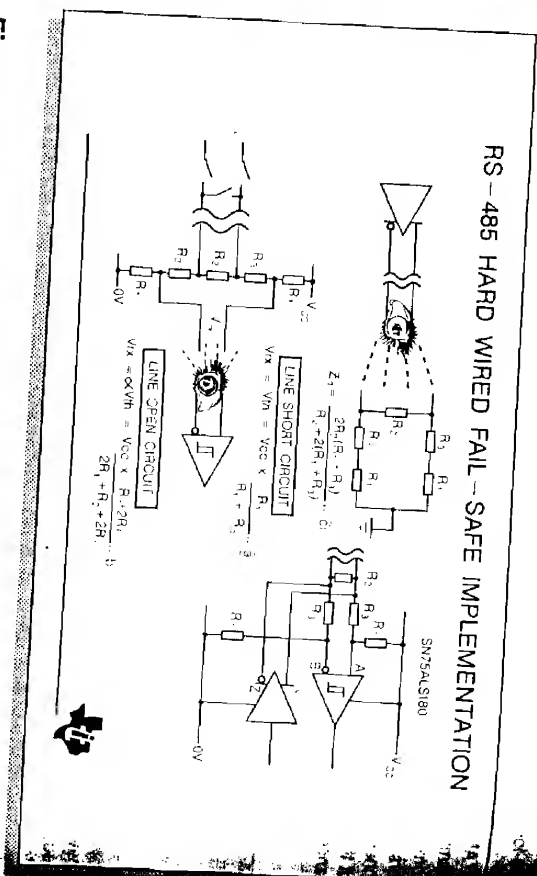
The AM26C32 is a quadruple line receiver for balanced and unbalanced digital data transmission. Conformance to the EIA standards RS-422-A and RS-423-A and CCITT recommendation V.11 is guaranteed. The enable function is common to all receivers and offers a choice of either active-high or active-low inputs. Three-state outputs permit connection to a digital data bus. Fail safe circuitry design on the receiver input side ensures that the outputs will remain in a high state even if the inputs are left open. This reduces the chances of incorrect data interpretation.

Notes

# Products and Applications For EIA RS-485

## Protecting Against Data Corruption

One noted feature offered by the AM26C02 receiver was an built-in fail safe feature. This feature is also a requirement in many RS-485 applications, however its usefulness need be considered and understood at an application level.



**Figure 15 - RS-485 Hard Wired Fail safe**

## The need For Fail safe Protection

In any party line interface system, with multiple driver/receivers, there will be long periods of time when the driving devices are inactive. This state known as line idle occurs when the drivers place their outputs into a high impedance state. During line idle, the voltage along the line is left floating, i.e. indeterminate - neither logic high or logic low. As a result the receiver could be falsely triggered into either a logic high or a low logic state, depending upon the presence of noise and the polarity of the floating lines. This is obviously undesirable as the circuitry following the receiver could interpret this as valid information. The receiver should be able to detect such a situation and place its outputs into a known, and predetermined state. The name given to methods which ensure this condition is called **fail safe**. An Additional feature which a fail safe should provide is to protect the receiver from shorted line conditions which can again cause erroneous processing of data and/or receiver damage.

There are several ways to implement a fail safe, including a hard-wired fail safe using line bias resistors or protocols. Protocols, although complicated to implement, are the preferred method and are discussed in more detail following this section. However since most system designers, hardware designers in this case, prefer to implement such functions in hardware hard-wired fail safe is often implemented.

Hard wired fail safe should provide a defined voltage across the receiver's input whether or not the line is shorted to either supply rail or is left open circuited. The fail safe should also be incorporated into the line termination network when at the extremes of the line.

## Internal Fail safe

Manufacturers have gone part way to facilitating fail safe design by including some form of open line fail safe circuitry within the integrated circuits. Unfortunately, due to power consumption constraints, the extra circuitry has proved little use. The extra circuitry is quite often just a large pull-up resistor on the non-inverting receiver input, and a large pull-down resistor on the inverting input of the receiver. These resistors are normally in the range of 100kΩ, and so when used in conjunction with line termination resistors to form a potential divider, only a few milli volts are generated. As a result this voltage (receiver threshold voltage) is insufficient to switch the receiver. In effect, to use these internal resistors no line termination resistors can be used, which reduces the allowed reliable data rate enormously.

## External Fail safe-Open Line Conditions

A more reliable way of offering open line fail safe is to use external pull-up and pull-down resistors. There two basic ways of doing this; one way is to polarise the line with the pull-up/pull-down resistors and use these resistors to match the line impedance. Another way is to use larger polarising resistors while using an extra resistor to terminate the line. The first idea has one advantage in that it provides a low impedance path to an a.c. ground, so that any currents induced on to the line have a low impedance path to ground. However a problem is encountered with this method because the driver output now has to drive very much lower impedances. If the driver output current capability is poor the device could easily go into output short circuit current limit. The second way, although requiring an extra resistor will not load the driver's output to such an excess.

## Notes

Placing external pull-up and pull-down resistors  $R_1$  on the non-inverting and inverting inputs of the receiver will produce open circuit fail safe. Terminating the transmission line with its characteristic impedance  $Z_0$  produces a potential divider between  $2R_1$  and  $Z_0$ . The voltage formed across the line,  $V_{oc}$ , equals

$$V_{oc} = V_{cc} \times \frac{Z_0}{2R_1 + Z_0}$$

Devices meeting the RS-485 receiver threshold voltage specifications require  $V_{oc}$  to be greater than 200mV. From this the relationship of  $R_1$  to  $Z_0$  can be derived:

$$R_1 = Z_0 \times \frac{1}{2} \times \frac{V_{cc} - V_{oc}}{V_{oc}}$$

With  $V_{cc} = 5V$ ,  $V_{oc} = 200mV$  and  $Z_0 = 100\Omega$ , yields  $R_1 = 1.2k\Omega$ .

Biasing the receiver in this way will only provide open line fail safe, it will not provide shorted line fail safe. However, when using transceivers it is not possible to provide shorted line fail safe configurations, this is a result of the driver and receiver sharing the same i.c. pins. Hence for devices like the SN75ALS176 this open line configuration the optimum fail safe available.

### External Fail safe-Shorted Line Conditions

To implement protection from the shorted line condition, further resistors are required. When the line is shorted the transmission line's impedance goes to zero and the termination resistors will also be shorted. Putting extra resistors in series with the input to the receiver can provide shorted line fail safe protection.

The extra resistors,  $R_3$  in the figure, can only be added when using devices with separate driver outputs and receiver inputs. So internally wired transceivers cannot be used to offer shorted line fail safe. If this form of protection is required then a device such as the SN75ALS180, with its separate driver outputs and receiver inputs, should be used. If a transceiver type device was used then the extra resistors  $R_3$  would cause extra attenuation of the output signal. The ALS180 will have its driver outputs fed directly to the line, bypassing resistors  $R_3$ .

### Calculating the Resistor Values

If the line became shorted then  $R_2$  would be removed leaving a voltage across the receiver inputs of:-

$$V_{rx} = V_{cc} \times R_3 / (R_1 + R_3)$$

(a).

For RS-485 and 422A applications the standard specifies  $V_{rx}$  to be greater than 200mV. So  $V_{rx} = V_{in} = 200mV$ . Using this figure, along with the minimum permissible supply voltage for the devices gives a relationship between  $R_1$  and  $R_3$ .

When the line goes into a high impedance state the receiver will see the two  $R_3$  in series with  $R_2$  plus the two  $R_1$ 's pulling up and down on either input. The receiver input voltage will now be:

$$V_{rx} = V_{cc} \times (R_2 + 2R_3) / (2R_1 + R_2 + 2R_3) \quad (b).$$

Relating this new  $V_{rx}$  to the minimum specified in the standard,  $V_{th}$ , gives:

$$R_1 = \frac{1}{2} R_2 \times \left[ \frac{(V_{cc} - \alpha V_{th})(V_{cc} - V_{th})}{(V_{cc} - V_{th})} \right] / (\alpha - 1) V_{th} V_{cc}$$

$$R_3 = R_2 \times (V_{cc} - V_{th}) / V_{th}$$

The transmission line will see an effective line termination resistance of  $R_2$  in parallel with twice the sum of  $R_1$  and  $R_3$ . This should match the transmission line's characteristic impedance,  $Z_0$ , therefore

$$Z_0 = 2R_2 \times \frac{R_1 + R_3}{2R_1 + R_2 + 2R_3} \quad (c)$$

Combining equations (a), (b) and (c) yields the following equations for  $R_1$ ,  $R_2$  and  $R_3$ :

$$R_1 = \frac{1}{2} Z_0 \times \frac{(V_{cc} - V_{th})^2}{(\alpha - 1) V_{th} V_{cc}}$$

$$R_2 = Z_0 \times \frac{V_{cc} - V_{th}}{V_{cc} \alpha V_{th}}$$

$$R_3 = \frac{1}{2} Z_0 \times \frac{V_{cc} - V_{th}}{\alpha - 1 V_{th}}$$

Notes

In this application assuming the supply voltage is 4.5V and  $V_{th} = 200mV$  with an a value of 1.5 and driving a line with characteristic impedance of  $120\Omega$  yields the following values:-

- $R_1 = 2.2k\Omega$
- $R_2 = 120\Omega$
- $R_3 = 110\Omega$

The values of  $R_1$ ,  $R_2$ , and  $R_3$  only apply for receivers at the extreme of the line: if there are more receivers on the line then fail safe can be accomplished by multiplying the values of  $R_1$  and  $R_3$  by half of the number of receivers on the line. This is done by assuming the values of  $R_1$  resistors are the same, all  $R_1$  resistors are the same, and that all  $R_3$  resistance will be divided by half the number of receivers. If there is a large number of receivers on the line there is a danger of  $R_3$  becoming too large and forming a large potential divider with the input resistance of the receiver, normally around  $18k\Omega$ .

### Use of Protocols- Synchronous Serial Communication

The use of line terminations to effect a fail safe is not a recommended practice. The recommended practice is to use software protocols. Protocols come in many forms (two of which are explained below) and provide a set of rules which define the meaning and order in which data should be sent. In particular, they can be used to provide a fail safe feature and be used to avoid contention. Contention occurs when several drivers try to address the link at the same time. This can lead to high current sinking or sourcing leading to excessive thermal dissipation in the drivers. Fail safe is ensured by allowing the receiving station to respond to valid data only. This is achieved by sending a preamble before each data packet. The preamble consists of a pre-determined pattern of bits, which signals to the receiver that valid data is about to follow. Anything other than this preamble should be ignored by the receiver.

#### Parity Line Protocol Formats

Parity line applications use either half duplex or full duplex transmission. Half duplex transmission mode is where two terminals (a driver and receiver) can communicate with each other bidirectionally over the same link, but they cannot transmit simultaneously. A number of driver/receiver pairs. Full duplex communications involves the simultaneous, two way flow of data from driver/receiver pairs.

A communication line used in a multiplexed operation such as the half duplex parity line system reduces wiring costs when compared to the simplex operation (simplex one driver for control of the multiplexing does require complex protocol or handshaking circuits).

- A typical (simplified) protocol sequence would contain the following elements:
- i) Driver requests access to communication link (bus)
  - ii) Link controller responds to request and gives go ahead when bus is free
  - iii) Driver gains bus mastership and sends data which is preceded by a destination code
  - iv) Receiver sends an acknowledgement
  - v) Driver receives confirmation and releases the bus

#### USE OF PROTOCOLS - SYNCHRONOUS SERIAL COMMUNICATION

- Correct Use of Protocols Ensures Complete Control Over the Link
  - Provides Fail Safe
  - Eliminates Contention
- Receivers are Synchronised by either:
  - Clock Pulses Embedded Within Data
  - Separately Generated Clock Pulse
- Byte Synchronisation
  - Sync Characters:  $0x55, 0xA5, 0x4D, 0x5D, 0x13, 0x1B, 0x33, 0x3B, 0x7F, 0xFF$
  - Synchronisation is by Special Sync Characters:  $815NCGMONOSINC$
- Bit Synchronisation
  - Half Duplex Operation
  - Synchronisation is Similar to Byte Sync Method
- The Receiver Divides up the Characters Using Two Methods
  - Byte Synchronisation
  - Bit Synchronisation
- Duplex Operation
  - SDLC
  - HOLL
  - ADCCP

Figure 15a - Use of Protocols in Synchronous Serial Communications

#### Synchronization

Some form of synchronization is necessary for the receiver to determine the start and finish of the received bits. Two schemes, with many variations, are adopted; *Asynchronous* and *synchronous*.

#### Notes

Asynchronous, or start-stop bit communication, uses a system where characters are sent one at a time, without necessarily having any fixed time relationship between each other. In such a case the driver sends start bits followed by the information field, followed by one or more stop bits. This informs the receiver that information data will follow the start bit and will end prior to the stop bit. The data is usually broken into small groups of 8-bits, one byte, which is preceded with a start bit and concluded with a stop bit. This is one of the schemes employed by RS-232.

Synchronous transmission is used to transmit complete blocks of data at one time. In synchronous transmission the duration of each bit is the same. With all characters being the same length the receiver only has to identify the first character and then clock the others in at a predetermined rate.

Serial synchronous communication uses a similar scheme and either embeds the timing information in the data or provides a separate clock signal. However the bit stream still has to be divided up into the individual characters. There are two main methods of achieving character synchronization: *Byte synchronization* and *bit synchronization*.

Byte synchronization, one of the first synchronous methods to be introduced is best known by IBM's bisync and monosync. Synchronization is achieved by using special SYNC characters which are transmitted in between data packets. The receiver continually monitors this transmission and uses it to synchronize itself. After receiving one (monosync) or two (bisync) sync pulses the receiver is said to be in the synchronized mode and is ready to receive data. Synchronization is ensured by re-sending the sync bits every few hundred characters, for this reason data is grouped together in frames or packets which start with sync characters. Each frame is 8-bits long

The bisync protocol also defines a structure for a frame that includes control information and error checking capability. The figure shows the basic frame structure with the sync characters followed by the header field. SOH identifies the beginning of the header block. The header field is user defined and generally contains control specific information such as rest data link, message numbering priority, etc. Start of text, STX, identifies the end of the header field and defines the beginning of the text field. The text or data field contains application specific information which must be sent to the application controller intact. ETX signals end of text and CRC1 and CRC2 are used as cyclic redundancy check bits. Notice that STX, ETX etc., are the standard ASCII control codes. Bisync is essentially a half duplex system because each frame requires an acknowledge from the receiver before commencing with the next frame. Obviously sending acknowledging codes back and forth reduces the data rate, and to overcome this bit synchronization was developed.

SDLC (synchronous data link control), again made popular through IBM, was one of the first bit synchronization protocols available. The CCITT also adapted this standard for their high level data link (HDLC) protocol. Both are very similar to the CCITT X25 layer 2 packet switching local area networking standard. Initially bit sync looks very similar to byte sync, ie during data null periods sync pulses are sent over the link to synchronise the receiver and driver. However after the sync period the data may be grouped in any number of bits. Byte sync systems are restricted to 8-bit packets. In SDLC and HDLC, messages are formatted into frames with each frame being divided into fields. The start flag is the sync data while the

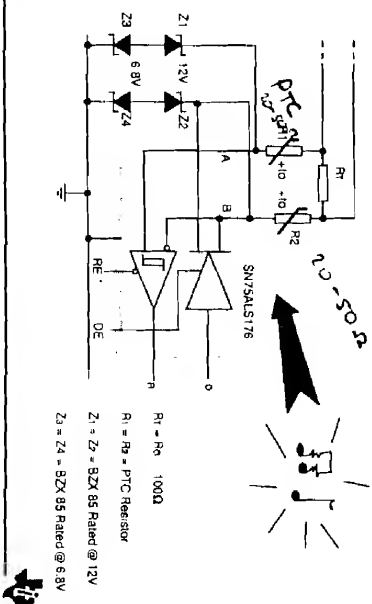
address field contains the destination address to select the required receivers. The control field can be configured as either an information field or supervisory field. The information field, which is the usual format, contains status information on the number of frames sent or received. Data field follows and contains application specific code. The supervisory or management frame is used to acknowledge successful receipt of data. CRC is used for error checking and flag is the next sync signal.

### Party Line Considerations

The following points should be considered for correct party line operation:

- i) Each driver must have a three-state logic capability, two logic states and a high impedance mode. Also at any one instance it is likely that all drivers could be in the high impedance state, thus leaving the bus floating. A receiver should be able to detect this situation and protect against any spurious information - fail safe design.
- ii) Receivers may oscillate if left unconnected, which might affect other used receivers in the same package. Therefore it is recommended that all unused receiver inputs should be tied to defined logic states.

## INPUT PROTECTION FOR NOISY ENVIRONMENTS



**Figure 16 - Input Protection In Noisy Environments**

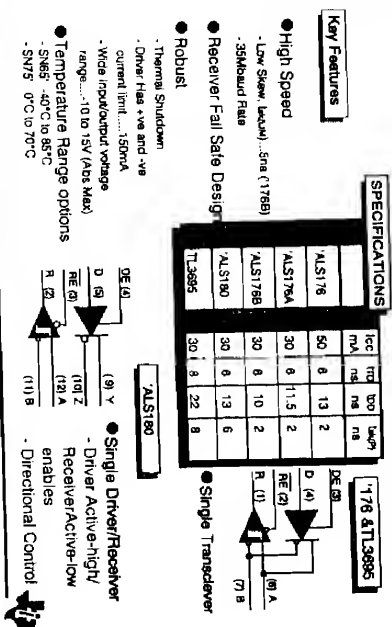
In addition to fail safe protection, applications often require protection against excessive noise voltages.

Often when sending data over long distances or in electrically hostile environments, i.e. factory automation, the noise immunity afforded by the differential transmission scheme, and in particular the wide common mode voltage range of RS-485 is insufficient. This figure shows how external diodes offer transient spike protection for the SN75ALS176 RS-485 transceiver.

$R_T$  is the usual termination resistance and is equivalent in value to the characteristic impedance of the line. Positive Temperature Coefficient resistors,  $R_1$  and  $R_2$ , provide current limiters for the diode chain. Provided their ambient temperature resistance is kept below  $50\Omega$ , they will be transparent during normal usage and will not alter the termination value or attenuate the driver output voltage.

$Z_1$  and  $Z_2$  are chosen to protect the input from positive spikes greater than 12 V whilst  $Z_3$  and  $Z_4$  protect the device from negative going spikes greater than -6.8 V.

## FOR HIGH SPEED/LOW POWER APPLICATIONS



**Figure 17 - SN75ALS176 Series for High Speed/Low Power Applications**

### Product Description

In the previous noise protection example, the SN75ALS176 was introduced. This device forms just part of a range of high performance single line driver/receiver options available for RS-422 and RS-485 applications. Some key benefits of this range are discussed in the following text.

The range of devices shown in the figure are all high speed low power monolithic integrated circuits, designed for bidirectional data communication on multipoint bus transmission lines. The SN65ALS176, SN75ALS176 series and TL3695 are single differential transceivers, while the SN65ALS180 and SN75ALS180 are a single differential driver/receiver pair.

All devices are designed for balanced transmission lines and meet EIA standards RS-422-A and RS-485, CCITT recommendations V.11 and X.27, and ISO 8482.1987(E).

### Notes

The SN65ALS176, SN75ALS176 series and TL3695 combine a 3-state differential line driver and a differential input line receiver, both of which operate from a single 5V power supply. The driver and receiver have active-high and active-low enables, respectively, which can be externally connected together to function as a direction control. The driver's differential outputs and the receiver's differential inputs are connected internally to form a differential input/output (I/O) bus port that is designed to offer minimal loading to the bus whenever the driver is disabled, or  $V_{OC} = 0V$ . This port features a wide positive and negative common-mode voltage range making the device ideal for party line applications. All devices are available in either 8-pin dual-in-line plastic (P) or 8-pin plastic small outline surface mount (D) packaging.

The SN75ALS180 contains many of the same features listed above. However, the driver outputs and receiver inputs are not internally connected together but are brought outside the chip, offering a separate driver and receiver function. For this reason the SN65ALS180 and SN75ALS180 are housed in a 14-pin dual-in-line plastic and 14-pin small outline plastic packages. This arrangement makes the SN75ALS180 ideal for full duplex operation.

### Product Differentiation

The SN75ALS176 series allows the designer to select between ac performance levels. The figure shows the maximum propagation delays and skew specification for the range. The SN75ALS176B offers the highest speed performance with a maximum differential output delay time of 10ns. With a minimum specified value of 5ns the device is capable of data rates in excess of 60 Mbaud (as per RS-485 specification).

Perhaps even more importantly, especially for high speed multi-channel applications (for example SCSI), is the low skew value,  $t_{sk(LIM)}$ . In this instance skew is specified as the difference between the maximum and minimum differential output delay times,  $T_{OD}$ . The SN75ALS176B has a minimum  $t_{sk(LIM)}$  value of 5ns. This value is used to determine the delays in signals between channels in the system. The pulse skew,  $t_{sk(P)}$ , is specified as a minimum value of 2ns (See 'A discussion of Skew' in the 'The specifications and Transmission line practicalities' section for further information).

The TL3695 provides the same functionality as the AL576 series of devices, but is aimed at lower performance lower cost systems.

As the application areas for multi-point differential standards standard widen so do the applications for the transceiver function.

On such emerging application is in the industrial environment, to connect between control modules (Masters) or process sensors (Slaves). For this reason Texas Instruments has included the 65 temperature range option which extends the temperature range from the basic 0°C to 70°C option to -40°C to 85°C.

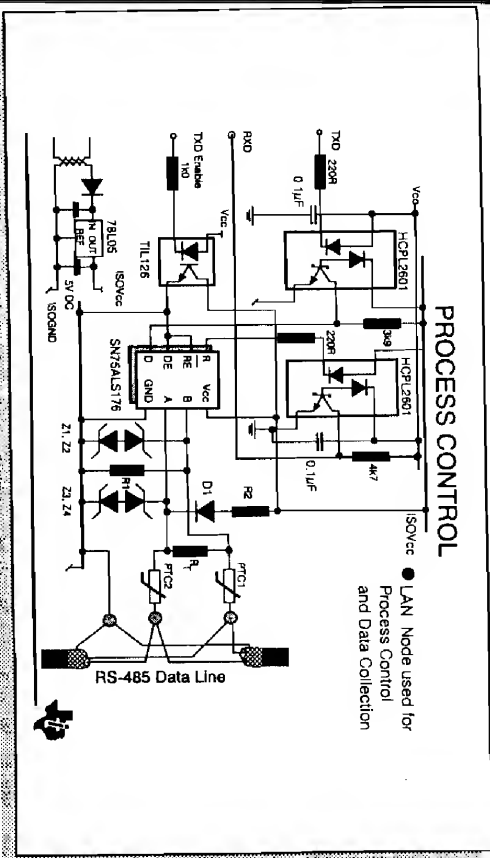


Figure 18 - Process Control Application

### Process Control

In the previous sections the need for line termination, receiver fail safe and noise protection was highlighted. All these elements can be found in an industrial process control and data collection application, which is shown in the figure.

### The need For Galvanic Isolation

The capability of meeting toughened noise legislation is a key requirement for many new end products and applications. Computer and industrial serial interfacing are areas where noise can seriously affect the integrity of data transfer, and a proven route to improved noise performance for any interface system is galvanic isolation.

### Notes

Such isolation in data communication systems is achieved without direct galvanic connection or wires between drivers and receivers. Magnetic linkage from transformers provide the power for the system, and optical linkage provides the data connection. Galvanic isolation removes the ground loop currents from data lines and hence the impressed noise voltages which affect the signal are also eliminated. Common mode noise effects can be completely removed and many forms of radiated noise can be reduced to negligible limits using this technique.

Taking a more practical view of where problems are likely to occur when using a galvanic interface, can be found in the industrial environment. For example consider the case when the interface node, shown in the figure, connects between a data logger and a host computer via the RS-485 link. When an adjacent electric motor is started up, a momentary difference in ground potentials at the data logger and the computer may occur due to a surge in current. If no isolation scheme is employed for the data communication path, data may be lost during the surge interval and in the worst case damage to the computer could occur.

### Circuit Description

The schematic shown forms an interface, one node, for a "distributed controlling, regulation and supervision (DCRS) system". Such a scheme could be used in a 'field bus' type application. Transmission takes place via a 2-wire bus, formed by a twisted-pair, shielded cable connected in a ring circuit. Other nodes, master or slaves, may be distributed along the bus in an arbitrary fashion and may be separated hundreds of metres in distance.

The bus driver used is the **SN65ALS176**, chosen for its high data rate capability and low power consumption. Low power is crucial in this type of application since many remote outstations will either be battery operated or require battery back-up capability. The '65 option was chosen for its industrial temperature range of -40°C to 85°C.

Transceiver protection circuitry is formed by  $Z_1, Z_2, Z_3$  and  $Z_4$  along with current limiters  $PTC_1$  and  $PTC_2$  (see previous example). Line termination is formed by a combination of  $R_1, R_1$  and  $R_2$ . The values of which can be calculated as follows:

$$R_1 = R_2 < 0.5 \times Z_0 \times [1 + V_{TH}/V_{CC}]$$

and

$$R_T = Z_0 [1 + V_{TH}/V_{CC}]$$

Using a cable with a characteristic impedance of  $Z_0 = 120\Omega$  and a desired  $V_{TH}$  of 200mV, requires  $R_1 = R_2$  to be around 1.6k $\Omega$  in value. The terminating resistor,  $R_T$  would be in the order of 124 $\Omega$ .

The inclusion of  $R_1 = R_2$ , provides a receiver fail safe to open line conditions by biasing the polarity of the line to a logic '1' under line idle conditions. The values of  $R_1 = R_2$  are best kept as low as possible to increase the noise rejection when the line is left floating, but they will place some loading onto the driver.

Galvanic isolation is afforded by means of three optocouplers/optoisolators. The HCPL2601 is chosen for its high data rate capability,  $t_p = 75ns$  (max), and its high voltage isolation.

The HCPL2601 is designed for use in high speed digital interfacing applications that require high voltage isolation between the input and output. Its use is highly recommended in extremely high ground noise and induced noise environments.

The HCPL2601 consists of a GaAsP light emitting diode and integrated light detector, composed of a photodiode, a high gain amplifier and a Schottky clamped open collector output transistor. An input diode forward current of 5mA will switch the output transistor low, providing an on state drive current of 13mA (eight 1.6mA TTL loads). A TTL input is provided for applications that require output transistor gating.

Housed in a single 8-pin dual-in-line plastic package the HCPL2601 is characterised for operation over the temperature range of 0°C to 70°C. The internal Faraday shield provides a guaranteed common mode transient immunity of 1000V/ $\mu s$ .

A 0.1 $\mu F$  capacitor has been connected between  $V_{CC}$  and ground to improve switching performance.

### Automotive Applications

Other emerging application areas are in the automotive industry, where even higher demands are made on the temperature range options of line interface circuits. One such area is the use of data transmission devices in low power data distribution systems, known as multiplex wiring.

Although the gradual trend in automotive applications is towards 'full multiplex wiring, where one common bus runs throughout the car (described below), an interim solution is to use several buses serving common systems.

### Notes

## MULTIPLEX WIRING

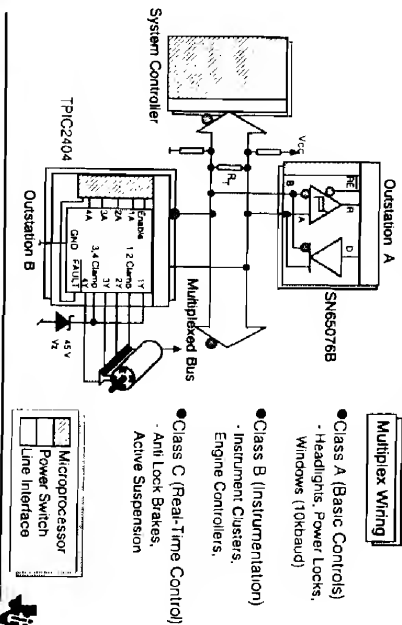


Figure 19 - Multiplex Wiring

Multiplex wiring is seen as a way to replace the costly and cumbersome conventional wiring harness that runs throughout the car. This harness, made up of thick copper wire and heavy duty switches is used to deliver the full load current from the battery to the load (actuator, lamp, etc). This approach as well as being costly is heavy, very difficult to test for faults, repair and is inflexible. Although the use of multiplexing is ultimately seen as giving cost advantages its more immediate use is to fix the above mentioned problems.

In a typical multiplexed system, a central controller will communicate with 'outstations' (which house both the control switches and load drivers) via a common distributed bus. Typical components of the system, shown in the figure, will require a system controller, differential line driver/receiver and intelligent power switch.

The central controller is responsible for implementing the communications protocol, which allows data, status, address and control information to be exchanged with the outstations. Part of the information exchange could be diagnostic data from the outstation power switch, used for driver instrument panel information or fault diagnosis during repair.

The central controller communicates over the bus via line interface devices. Due to the electrical hostile environment and the need for high reliability (especially in safety critical applications) a differential data transmission scheme is used which gives increased noise immunity.

The final requirement is for a local intelligent power device, which exchanges the low voltage TTL/CMOS logic level from the interface device to a high current, high voltage level to control the actuator. In addition to their power transfer characteristics, these devices should provide

simple error sensing capabilities which can detect device or actuator problems. Such a device could be the TPIC2404 which is a monolithic high-voltage high-current quadruple low-side switch.

Automotive data buses can be broken down into three main categories:

**Class A** buses include basic controls, such as headlights, power locks and windows.

**Class B** buses cover instrument clusters, engine controllers, trip computers and other areas requiring exchange of information.

**Class C** buses, which are the furthest from implementation, include real-time control applications, for example anti-lock brakes, active suspension systems, and other engine controls.

The application and position of the outstation dictates the temperature range required from the interface circuit. For example outstations situated in the engine compartment will require a wider operating range than an outstation situated behind the instrument cluster.

### Product Support

Texas Instruments has an on-going programme to provide interface devices which support all the major automotive standards. These standards include the SAE J1850 standard and European standards CAN and VAN. Of particular note are the LinBICMOS developments for the J1850 standard. These devices are differential current mode line/drive receive devices which contain over 300 logic gates for memory buffering, thus allowing message handling capability. Use of LinBICMOS provides the robustness, wide voltage ranges and extended temperature ranges required for automotive applications.

Early implementors of partial multiplex wiring systems have capitalised upon the advantages offered by the SN65176B device. However for real high temperature application, (i.e. outstation situated in the engine compartment) further temperature range extensions are required. For this reason the SN65076B was developed, and is characterised for operation from -40°C to 105°C. Special selections may extend this range further still.

The SN75076B achieves this high temperature range of operation by application optimisation, i.e. by eliminating all unnecessary functions the device's power dissipation can be kept to a minimum. For example, complicated enabling schemes are not required since most

### Notes

### Product Description

The SN65076B and SN75076B combine a differential line driver and a differential line input receiver, both of which operate from a single 5V power supply. The receiver has an active-low enable. The driver's differential outputs and the receiver's differential inputs are connected internally to form a differential input/output (I/O) bus port that is designed to offer minimal loading to the bus whenever the driver is disabled, or  $V_{CC} = 0V$ . This port features a wide positive and negative common-mode voltage ranges making the device ideal for parity-line applications.

Both devices are available in either 8-pin dual-in-line plastic (P) or 8-pin plastic small outline surface mount (D) packaging. The SN65076 is characterised for operation from -40°C to 105°C and the SN75076 is characterised for operation from 0°C to 70°C.



## Boost the Data Rate

Most RS-485 systems operate with a single twisted pair as the data transmission medium limiting the data transfer to asynchronous mode. In addition, the single line must also transfer receiver address, start and stop bits and a preamble to enable the receiver logic to distinguish between data or rubbish on an idle line. These additional transferred bits impact the speed of operation on the data line.

Alternatively, synchronised data transfer can be implemented by adding an additional sync. clock line as shown on the figure, and can be further complemented with the addition of a couple of handshake lines. The overall transfer of the "real data" can be significantly speeded up, as most of the control bits used in asynchronous mode will be eliminated from the data path.

## Notes

Specifically, synchronous data transfer benefits from applications where complete blocks of data can be transferred because the usual requirement in asynchronous transfer for breaking the data down in small groups of 8-bits (proceeded with a start bit and concluded with a stop bit) is eliminated.

Several terminals or station can be connected to this synchronised RS-485 system. The number of stations is only limited by the usual rules for RS-485. Daisy-chain connection between terminals is required unless each terminal is connected to the main data path via a short stub as the shown for terminal number N - 1.

### Why use the SN751177 and SN751178 ?

The SN751177 contains two drivers and two receivers in a single 16-pin package. Each pair of drivers and receivers has a common enable line. Upon transmission, both the data and sync. clock drivers are enabled allowing synchronous transfer of data. When shifting to receiver mode, both drivers are disabled, and the two receivers are enabled simultaneously. Due to the complementary enabling schemes for drivers and receivers (logic 1 enables the drivers but disables the receivers, and logic 0 the opposite). It is possible to connect both driver and receiver enable signals to the same control output. This reduces the number of I/O's required.

The SN751178 also contains two drivers and two receivers in a 16-pin package, but offers a different enabling pattern. The two receivers are always active and listen continuously to the handshake lines as necessary. However, the two drivers can be independently enabled as required by a handshaking scheme.

In summary, the SN751177 and SN1178 offer a simple but versatile solution synchronous transfer of data at high speeds. Their configuration as two driver/receiver pairs adds to the effectiveness of the application

## SN751177 & SN751178... DUAL DX/RX PAIRS

- Meets EIA Standard RS422-A, RS485 CCITT V.10 & V.11

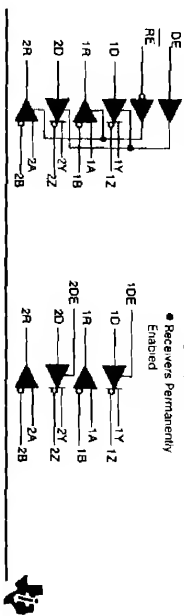
- Designed for Multipoint Transmission On Long Bus Lines in Noisy Environments

- Thermal Shutdown Protection

- Driver Features Positive and Negative Current Limiting

### SN751177

- Separate Driver & Receiver Enables



### Key Specifications

100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700	710	720	730	740	750	760	770	780	790	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970	980	990	1000	1010	1020	1030	1040	1050	1060	1070	1080	1090	1100	1110	1120	1130	1140	1150	1160	1170	1180	1190	1200	1210	1220	1230	1240	1250	1260	1270	1280	1290	1300	1310	1320	1330	1340	1350	1360	1370	1380	1390	1400	1410	1420	1430	1440	1450	1460	1470	1480	1490	1500	1510	1520	1530	1540	1550	1560	1570	1580	1590	1600	1610	1620	1630	1640	1650	1660	1670	1680	1690	1700	1710	1720	1730	1740	1750	1760	1770	1780	1790	1800	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120	2130	2140	2150	2160	2170	2180	2190	2200	2210	2220	2230	2240	2250	2260	2270	2280	2290	2300	2310	2320	2330	2340	2350	2360	2370	2380	2390	2400	2410	2420	2430	2440	2450	2460	2470	2480	2490	2500	2510	2520	2530	2540	2550	2560	2570	2580	2590	2600	2610	2620	2630	2640	2650	2660	2670	2680	2690	2700	2710	2720	2730	2740	2750	2760	2770	2780	2790	2800	2810	2820	2830	2840	2850	2860	2870	2880	2890	2900	2910	2920	2930	2940	2950	2960	2970	2980	2990	3000	3010	3020	3030	3040	3050	3060	3070	3080	3090	3100	3110	3120	3130	3140	3150	3160	3170	3180	3190	3200	3210	3220	3230	3240	3250	3260	3270	3280	3290	3300	3310	3320	3330	3340	3350	3360	3370	3380	3390	3400	3410	3420	3430	3440	3450	3460	3470	3480	3490	3500	3510	3520	3530	3540	3550	3560	3570	3580	3590	3600	3610	3620	3630	3640	3650	3660	3670	3680	3690	3700	3710	3720	3730	3740	3750	3760	3770	3780	3790	3800	3810	3820	3830	3840	3850	3860	3870	3880	3890	3900	3910	3920	3930	3940	3950	3960	3970	3980	3990	4000	4010	4020	4030	4040	4050	4060	4070	4080	4090	4100	4110	4120	4130	4140	4150	4160	4170	4180	4190	4200	4210	4220	4230	4240	4250	4260	4270	4280	4290	4300	4310	4320	4330	4340	4350	4360	4370	4380	4390	4400	4410	4420	4430	4440	4450	4460	4470	4480	4490	4500	4510	4520	4530	4540	4550	4560	4570	4580	4590	4600	4610	4620	4630	4640	4650	4660	4670	4680	4690	4700	4710	4720	4730	4740	4750	4760	4770	4780	4790	4800	4810	4820	4830	4840	4850	4860	4870	4880	4890	4900	4910	4920	4930	4940	4950	4960	4970	4980	4990	5000	5010	5020	5030	5040	5050	5060	5070	5080	5090	5100	5110	5120	5130	5140	5150	5160	5170	5180	5190	5200	5210	5220	5230	5240	5250	5260	5270	5280	5290	5300	5310	5320	5330	5340	5350	5360	5370	5380	5390	5400	5410	5420	5430	5440	5450	5460	5470	5480	5490	5500	5510	5520	5530	5540	5550	5560	5570	5580	5590	5600	5610	5620	5630	5640	5650	5660	5670	5680	5690	5700	5710	5720	5730	5740	5750	5760	5770	5780	5790	5800	5810	5820	5830	5840	5850	5860	5870	5880	5890	5900	5910	5920	5930	5940	5950	5960	5970	5980	5990	6000	6010	6020	6030	6040	6050	6060	6070	6080	6090	6100	6110	6120	6130	6140	6150	6160	6170	6180	6190	6200	6210	6220	6230	6240	6250	6260	6270	6280	6290	6300	6310	6320	6330	6340	6350	6360	6370	6380	6390	6400	6410	6420	6430	6440	6450	6460	6470	6480	6490	6500	6510	6520	6530	6540	6550	6560	6570	6580	6590	6600	6610	6620	6630	6640	6650	6660	6670	6680	6690	6700	6710	6720	6730	6740	6750	6760	6770	6780	6790	6800	6810	6820	6830	6840	6850	6860	6870	6880	6890	6900	6910	6920	6930	6940	6950	6960	6970	6980	6990	7000	7010	7020	7030	7040	7050	7060	7070	7080	7090	7100	7110	7120	7130	7140	7150	7160	7170	7180	7190	7200	7210	7220	7230	7240	7250	7260	7270	7280	7290	7300	7310	7320	7330	7340	7350	7360	7370	7380	7390	7400	7410	7420	7430	7440	7450	7460	7470	7480	7490	7500	7510	7520	7530	7540	7550	7560	7570	7580	7590	7600	7610	7620	7630	7640	7650	7660	7670	7680	7690	7700	7710	7720	7730	7740	7750	7760	7770	7780	7790	7800	7810	7820	7830	7840	7850	7860	7870	7880	7890	7900	7910	7920	7930	7940	7950	7960	7970	7980	7990	8000	8010	8020	8030	8040	8050	8060	8070	8080	8090	8100	8110	8120	8130	8140	8150	8160	8170	8180	8190	8200	8210	8220	8230	8240	8250	8260	8270	8280	8290	8300	8310	8320	8330	8340	8350	8360	8370	8380	8390	8400	8410	8420	8430	8440	8450	8460	8470	8480	8490	8500	8510	8520	8530	8540	8550	8560	8570	8580	8590	8600	8610	8620	8630	8640	8650	8660	8670	8680	8690	8700	8710	8720	8730	8740	8750	8760	8770	8780	8790	8800	8810	8820	8830	8840	8850	8860	8870	8880	8890	8900	8910	8920	8930	8940	8950	8960	8970	8980	8990	9000	9010	9020	9030	9040	9050	9060	9070	9080	9090	9100	9110	9120	9130	9140	9150	9160	9170	9180	9190	9200	9210	9220	9230	9240	9250	9260	9270	9280	9290	9300	9310	9320	9330	9340	9350	9360	9370	9380	9390	9400	9410	9420	9430	9440	9450	9460	9470	9480	9490	9500	9510	9520	9530	9540	9550	9560	9570	9580	9590	9600	9610	9620	9630	9640	9650	9660	9670	9680	9690	9700	9710	9720	9730	9740	9750	9760	9770	9780	9790	9800	9810	9820	9830	9840	9850	9860	9870	9880	9890	9900	9910	9920	9930	9940	9950	9960	9970	9980	9990	10000
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Figure 21 - SN751177 and SN751178 Dual DX/RX Pairs

### Product Description

The SN751177 and SN751178 dual differential drivers and receivers are monolithic integrated circuits designed for balanced multipoint bus transmission at data rates up to 10Mbaud. They are designed to improve the performance of full-duplex data communications over long bus lines and meet EIA standards RS-422, RS-485 and several CCITT recommendations.

The SN75117 and SN751178 driver outputs provide limiting for both positive and negative currents and thermal shutdown protection from line fault conditions on the transmission line.

The receiver features include a high input impedance of 12K $\Omega$ , an input sensitivity of  $\pm 200$ mV over a common-mode input voltage range of -12 V to +12V and a typical hysteresis of 50 mV. A fail safe feature ensures that if the receiver inputs are open, line idle, the receiver outputs will always be high.

### Notes

The SN751177 drivers and receivers are enabled in pairs. An active-low RE enables both receivers, whilst an active-high DE enables both drivers. The SN751178 has an enable for each driver, whilst its receivers are permanently enabled. Choice of enabling scheme offers flexibility in application, allowing use as repeaters, direction control or data lines in full, half duplex and simplex modes of operation.

Both the SN751177 and SN751178 are characterised for operation from -20°C to 85°C, and are available in 16-pin dual-in-line plastic packages.

Future developments of these products will include ALS-Impact™ versions resulting in lower power consumption and increased speed.

Impact is a trade mark of Texas Instruments

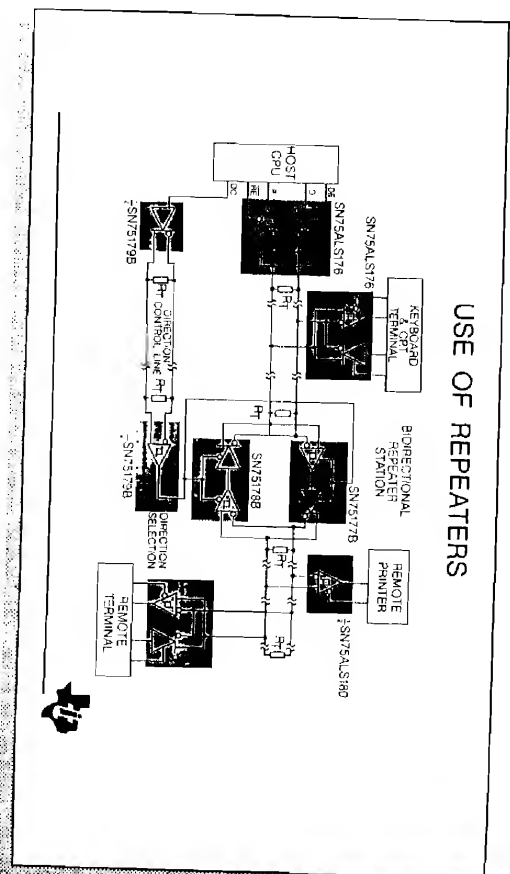


Figure 22 - Use of Repeaters

### The Need for Repeaters

The major advantage of RS-485 is that it permits multiple drivers and receivers to operate over a 2-wire bus, thus setting up a party-line architecture. When such a data communication bus system is transmitting data over lines as long hundreds of meters or even thousands of metres, attenuation is often experienced between a driver at one end and a receiver in the other end (over long distances the cable's resistance does have an effect). Such systems can benefit from the use of signal restoration by means of bus repeaters.

Similarly, when more than 32 unit loads are connected to a bus, requirements for additional buffering arise. A bus repeater has in this function a different role from restoring the original signal namely to drive another 32 unit loads.

### Repeater Solutions

Bus repeaters in data communication systems receives degraded signals from the transmission line, squares up the pulses, and retransmits the signals onto the line to the receiving station. Because the original transmitted signal is restored (squared up), the communication system becomes less susceptible to noise and other types of interference on the lines.

The shown "use of repeaters" application for bidirectional control of an RS-485 bus with long transmission lines is implemented with a bidirectional repeater station. Two types of repeaters are available: One version is enabled by a logic 1 control signal and the other by a logic 0. Thus, without any glue logic you can design a fully bidirectional repeater station that restores signals from both directions on a line

Enabling and disabling of the repeater drivers and receivers and thereby the data direction is controlled by the host microcontroller. In data communication systems where no host CPU controls the data direction, intelligence needs to build into the repeater station to maintain system control. This allows also for independent communication on each side of the repeater station providing additional flexibility and faster overall data exchange.

### Recommended Products

Dedicated products designed specifically for repeater purposes are the SN75177B and SN75178B. Employing these repeater devices in simple repeater stations as the shown, completely eliminates the need for any glue logic due to their enabling scheme. For repeater stations including protocol controllers may also benefit from devices such as SN751177 and SN1178 with their multiple drivers and receivers.

# PRODUCTS FOR RS-422 and RS-485

Line Interface		
Device	No. of Drivers	No. of Receivers
AM2BC1 *	4	4
AM2BC12 *	1	1
SN75ALS176A/B	3	3
SN75ALS170	3	3
SN75ALS171	1	1
SN75ALS180	4	4
SN75ALS191	4	4
SN75ALS192	4	4
SN75ALS193	4	4
SN75ALS194	4	4
SN75ALS195	4	4
SN75ALS197E	1	1
SN75ALS198E	1	1
SN75ALS199E	1	1
TL3695	2	2
SN751177	2	2
SN751178	2	2

Industry's Widest Selection of  
Differential Line Driver/Receiver  
Products



Figure 23 - New Products For RS-422 and RS-485

The figure shows the range of devices available for the EIA RS-422 and RS-485 standards. Of particular note is the trend towards devices combining low-power and high-speed capabilities which also offer a variety of enabling schemes and multiple driver/receiver combinations. Also of note are the SN75ALS170, SN75ALS171 and SN75LBC176, these are the subjects of the following section.

## The ANSI Small Computer Systems Interface